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Mazdoor Kisan Shakti Sangathan

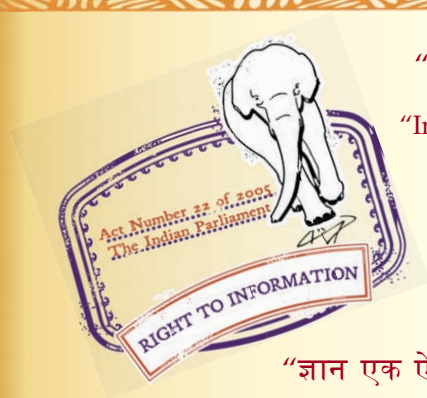
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IS 11358 (1987): Glossary of terms and symbols relating to rock mechanics [CED 48: Rock Mechanics]



“ज्ञान से एक नये भारत का निर्माण”

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“Invent a New India Using Knowledge”



“ज्ञान एक ऐसा खजाना है जो कभी चुराया नहीं जा सकता है”

Bhartrhari—Nitiśatakam

“Knowledge is such a treasure which cannot be stolen”

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Indian Standard

**GLOSSARY OF TERMS AND SYMBOLS
RELATING TO ROCK MECHANICS**

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Indian Standard

GLOSSARY OF TERMS AND SYMBOLS RELATING TO ROCK MECHANICS

0. FOREWORD

0.1 This Indian Standard was adopted by the Bureau of Indian Standards on 31 August 1987, after the draft finalized by the Rock Mechanics Sectional Committee had been approved by the Civil Engineering Division Council.

0.2 A series of Indian Standards covering various aspects of rock mechanics are being formulated which will cover a large number of terms relating to this field. The extensive use of these terms has necessitated the preparation of this glossary so that all the terms could be brought out in one standard and reference to this Indian Standard could be given in the other standards being formu-

lated in this field, covering the method of test, code of practice and other related subjects. Prior to preparation of this Indian Standard, some of the terms relating to rock mechanics were covered in IS : 2809 - 1972* which is also under revision and during its revision the terms relating to rock mechanics will be deleted. However, some of the common terms which are in common use in both the fields appear in both of these standards.

*Glossary of terms and symbols relating to soil engineering (first revision).

1. SCOPE

1.1 This standard covers the definitions of terms and symbols relating to field of rock mechanics.

2. DEFINITIONS

2.0 For this standard, the following definitions shall apply.

A

2.1 A Line (Minimum Excavation Line) — A dimensional line in a tunnel inside of which rock projections are not permitted,

or

It is the line within which no unexcavated material of any kind and no supports other than permanent structural steel supports shall be permitted to remain.

2.2 Acoustic Emission — See microseismic noise.

2.3 Active Fault — A fault along which there is recurrent movement, that is usually indicated by small, periodic displacement or seismic activity.

2.4 Adit — A nearly horizontal passage leading from the surface to an underground chamber or passage connecting two such chambers,

or

Tunnel into an abutment for exploratory or test purpose,

or

Opening in the face of a dam for access to galleries or operating chambers,

or

Access tunnel to a tunnel for construction or maintenance purposes.

2.5 Air Lock — A compartment in which air pressure can be equalized to the compressed air inside a shield-driven tunnel as well as the outside air to permit passage of men and materials.

2.6 Allowable Brearing Pressure (q_a) — It is the allowable pressure transmitted by a foundation to the rock mass such that no damage occurs either in the structure or in the rock mass. It is based upon safe bearing pressure (satisfying criteria of shear, total and differential settlement and tilt), correction factors, and past experience and judgement of experts.

2.7 Angle of Draw Subsidence — It is defined as the angle between the vertical and the line connecting the limit of excavation with the point of zero subsidence. This is also called the limiting angle of influence.

2.8 Angle of Friction of Fractures — It is the sliding angle (tangential) of friction at normal pressure of 10 kg/cm² across joints. It is classified as A_1, A_2, A_3, A_4, A_5 for angle of friction of fractures of $>45^\circ, 35-45^\circ, 25-35^\circ, 15-25^\circ$ and $<15^\circ$, respectively. This notation is used in basic geotechnical description (BGD).

The sliding angle of friction of joints is further measured in two parts as follows:

- a) *Peak Sliding Angle of Friction* — It is the sliding angle of friction for the maximum or peak shear strength observed in a shear test across a joint.
- b) *Residual Sliding Angle of Friction* — It is the sliding angle of friction for the state of residual strength of a joint which may

be obtained by subjecting the joint to excessive slip such that no further reduction in shear strength takes place.

2.9 Angle of Internal Friction, Peak (ϕ_p) — Angle of internal friction (that is, slope of strength envelope) corresponding to maximum shear stress in shear stress/displacement plot.

2.10 Angle of Internal Friction, Residual (ϕ_r) — Angle of internal friction corresponding to shear stress at large displacement (that is, corresponding to residual shear strength).

2.11 Anisotropy — A condition of a material having different properties in different directions. For example, the state of geologic strata of transmitting sound waves with different velocities in vertical and horizontal directions. Situation of a material having different moduli of deformation in different directions.

2.11.1 Transverse Anisotropy — The anisotropy of sedimentary deposits of rock mass is of very special nature and is called transverse anisotropy. (Only five elastic constants are sufficient to define the anisotropy of the rock mass).

2.12 Anticline — An arch-like fold (up-fold) in rocks, with the beds dipping in opposite direction from the crest.

2.13 Apron — A floor with lining of concrete, timber or other resistant material at the toe of a dam, bottom of a spillway or chute to prevent erosion from falling water of turbulent flow.

2.14 Arch — The configuration of the upper part of a tunnel section above the spring line or the crown or the curved roof of an underground opening (tunnel).

2.15 Arching — The transfer of load by shear from the yielding part of a rock mass to the adjoining less yielding or restrained part of mass.

2.16 Artesian Condition — Ground water that is under sufficient pressure to rise above the level at which it is encountered by a well, but which does not necessarily rise to or above the surface of the ground.

2.17 Asparities — These are small undulations along a discontinuity. There are two types of asparities called primary and secondary asparities. Primary asparities are major asparities while secondary asparities are micro-undulations of the primary asparities.

2.18 Attenuation — The amplitude of waves decrease as they travel through rock mass. This reduction in amplitude is known as attenuation. Attenuation is energy loss with distance per cycle.

2.19 Axial Young's Modulus (E) — It is the ratio of the axial stress change to the axial strain produced by the stress change for a cylindrical specimen tested in uniaxial compression.

It may be calculated using any of the following methods:

- a) *Tangential Young's Modulus, E_t* — This is the tangential Young's modulus at a stress level which is some fixed percentage of the ultimate strength and is generally 50 percent of the ultimate uniaxial compressive strength.
- b) *Average Young's Modulus, E_{ar}* — The average Young's modulus is defined as the average slope of more or less straight portion of the axial stress-strain curve.
- c) *Secant Young's Modulus, E_s* — The secant Young's modulus is usually measured from zero stress to some fixed percentage of the ultimate strength, generally 50 percent.

B

2.20 B Line (Pay Line) — A dimensional line in a tunnel outside of which excavation is not paid for,

or

The B-line is that line for which payment is made to the contractor for the underground excavation done in rock using conventional method of drilling and blasting.

2.21 Back Packing — Any material (usually granular) which is used to fill the empty space between the lagging and the rock surface in a tunnel.

2.22 Basic Geotechnical Description (BGD) — The basic geotechnical description of rock mass is based on five parameters, namely, rock name (geological description), layer thickness, fracture intercept, uniaxial compressive strength and angle of friction of fractures. For example, a zone of rock mass may be described as Quartz — L_2, F_4, S_3, A_2 , where L, F, S and A represent the last four parameters defined in the text.

2.23 Basic Sliding Angle of Friction of Joints (ϕ_b) — It is the angle of sliding friction between flat non-dilatant rock surfaces in dry or wet conditions. It is obtained from residual tests on flat unweathered rock surfaces.

2.24 Bearing Pressure (Safe) (q_s) — The load per unit area which can be safely supported by the ground (rock and/or soil).

2.25 Bed Rock — Any layer of rock underlying soil,

or

Geologically, the term denotes material underlying drift deposits,

or

It is the solid, undisturbed rock in place either at the ground surface or beneath superficial

deposits of gravel, sand, or clay.

2.26 Bedding Plane — A plane dividing sedimentary rocks of same or different lithology. The division planes which separate the individual layers, beds, or strata marking the boundary between a bed and the bed above and/or below it.

2.27 Bench — The unexcavated rock having a nearly horizontal surface which remains after a top heading has been excavated in a tunnel.

2.28 Bench Blasting — A method of blasting in quarries and open pits. The excavation proceeds in steps or in benches and rows of blast holes are drilled parallel to the free face.

2.29 Bending Strength — An alternative term for flexural strength (*see* tensile strength).

2.30 Blanket or Area Grouting — The process of grouting to a specified depth for the purpose of consolidation and/or reducing permeability.

2.31 Blastability — Index value of the resistance of a rock formation to blasting.

2.32 Blasting Cap or Detonator — A small tube containing a flashing mixture for firing explosives.

2.33 Blocking — Wood on blocks placed between the excavated surface of a tunnel or a shaft and the main bracing system.

2.34 Blow-Out — A sudden loss of a large amount of compressed air at the top of a shield.

2.35 Bond Strength — The stress required to rupture the bond in a material, or between two kinds of material cemented one to another (for example, a concrete block cemented on rock).

2.36 Bore Log — The detailed record of the rocks passed through in drilling, where accurate logs constitute a valuable source of sub-surface information.

2.37 Borehole — A hole drilled into the ground for purpose of extracting soil samples and/or rock cores for examination and testing.

2.38 Borehole Extension (of Extensometer) — Elongation in the axis of a borehole in *in-situ* rock, due to extension.

2.39 Bottom Charge — Concentrated explosive charge at the bottom of a blasthole.

2.40 Boulder — A more or less rounded block of fragment of rock and of average dimension 300 mm or greater. Usually boulders are rounded by being carried or rolled along by water or ice, sometimes also by weathering in place, in which case they are known as boulders of weathering, disintegration or exfoliation.

2.41 Breast Board — Timber planks to support the face of tunnel excavation in soft ground.

2.42 Breccia — A coarse-grained elastic rock composed of large, angular and broken rock fragments that are cemented together in a finer-grained matrix, and that can be of any composition, origin or mode of accumulation.

2.43 Brittle — A material is said to be in a brittle state or brittle under conditions in which its stability to resist load decreases suddenly with increasing deformation.

2.44 Broken Zone (Around Tunnel) — The broken zone is defined as the area bounded by the locus of points around the tunnel opening where the induced tangential stress exceeds the *in-situ* strength of rock mass. The rock mass is in elastic state beyond the broken zone.

2.45 Buckling — The twisting or forcing out of shape of a structural member or rock layer under compression by an excessive or eccentric load.

2.46 Bulk Volume (V_b, L^3) — The volume contained within the gross external dimensions of a rock specimen, denoting the volume occupied by the grains, voids and intergranular infillings.

2.47 Bump (Coal Mines) — Bump is defined as a strong seismic shock resulting from a failure or a sudden displacement at some point in the rock surrounding an underground opening.

2.48 Burden — Distance between charge and free surface in direction of throw.

2.49 Burst — To break suddenly into pieces from impact or from pressure within.

C

2.50 Cable Anchor — Cable are used to prestress the rock mass around large openings or anchor the civil engineering structures into the rock foundation. These anchors are known as cable anchors.

2.51 Camouflet — The underground cavity created by a fully contained explosive.

2.52 Cancellation Pressure — This is the hydraulic pressure in the flat jack at which the displacements created by cutting the slot are cancelled.

2.53 Catastrophic Failure — A failure of large rock mass giving almost no warning. A sudden failure.

2.54 Cavern (Sinkhole) — A subterranean hollow; an underground cavity (most frequent in limestones and dolomites).

2.55 Cavities — Sinkholes and other sorts of open cavities are most commonly formed in limestone, gypsum, and salt.

2.56 Charge — The amount of explosive used in a blasthole.

2.57 Circular Wedge Failure — When the material is very weak, as in a soil slope, or when the rock mass is very heavily jointed or broken, as in a waste rock dump, the failure will be defined by a single discontinuity surface and will tend to follow a circular failure path.

2.58 Clastic Rock — A consolidated sedimentary rock composed principally of detritus transported into its place of deposition (for example, sandstones and shales as distinct from limestones and anhydrites).

2.59 Clay — Soil consisting of inorganic material, the particle size of which have diameters smaller than 0.002 mm.

2.60 Coefficient of Volumetric Expansion — This is the ratio between the increase in volume of rock mass and its initial volume.

2.61 Cohesion (c) — The property of rock particles to bind together, given by the vertical intercept or strength envelope, that is, of shear strength *versus* normal stress plot.

2.62 Compacting Zone (Around Tunnel) — zone within rock mass having tendency to undergo compaction near supports in squeezing ground.

2.63 Condition of Joints — This parameter includes roughness of joint surfaces, their continuity their opening or separation (distance between the surface), the infilling (gouge) material, and weathering of the wall rock.

2.64 Conformity — The relationship of adjacent beds not separated by a sedimentary discontinuity.

2.65 Consolidation Grouting — See grouting.

2.66 Continuum — A continuum is a mathematical abstraction applied to a large collection of material particles.

2.67 Controlled Blasting — Blasting designed to preserve the integrity of the remaining rocks, for example, smooth blasting or presplitting.

2.68 Core — Any single solid piece or rock in cylindrical shape obtained by drilling process.

2.69 Core Loss — Percentage of loss of core from a drillhole with respect to the total drill run.

2.70 Core Recovery — Percentage of core recovered from a drillhole with respect to the total core run.

2.71 Crack — Rocks have small cracks which are formed either between the boundaries of the mineral grains or develop as transgranular fractures.

2.72 Crater — A pit formed on the ground surface due to an underground explosion.

2.73 Creep — Time-dependent deformation or strain. Deformation that occurs over a period of time when a material is subjected to constant

stress at constant temperature. Slow deformation that results from long application of stress. An imperceptibly slow, more or less continuous, downward and outward movement of slope-forming rock or soil.

2.74 Creep Strength — Maximum stress required to bring about a specified amount of creep in a specified time.

2.75 Critical Stress — Maximum and minimum compressive stress on the boundary of an opening.

2.76 Cross Joints — These are the joints which generally occur in a direction normal to bedding planes. These are invariably discontinuous joints.

2.77 Crown — The highest point of the cross-section. In tunnel linings, the term is used to designate either the arched roof above spring lines, or all of the lining except the floor or invert.

2.78 Crust — The outermost layer or shell of the earth lying above the Mohorovicic discontinuity.

2.79 Curtain Grouting — The process of grouting in which one or more lines of holes are grouted to specified depths in order to create a barrier against seepage.

2.80 Cut-Off — A wall or diaphragm of concrete, steel, grout wall, or a slurry trench or trench filled with duly compact impervious material for the purpose of reduction of seepage under a dam and rock foundation material, and to reduce uplift pressure on the base of a dam and other structural foundation.

2.81 Cycle Time — Cycle time is defined as the time required for various processes of excavation starting from drilling and blasting to mucking and support installation.

2.82 Cyclical Stress — Repeated stressing and destressing of material.

D

2.83 Damping — Reduction in the amplitude of vibration of a body or system due to dissipation of energy internally or by radiation.

2.84 Decomposition — The breaking down of minerals by themselves or in rocks through chemical processes, usually related to weathering.

2.85 Decoupling — The ratio of the radius of the blastholes to the radius of the charge. In general, a reducing of the strain wave amplitude by increasing the spacing between charge and blastholes.

2.86 Deformation Modulus (E_c) — In repeated loading-unloading tests, the ratio of stress, σ to the total strain (total strain = $\epsilon_{el} + \epsilon_{ir}$) is called the modulus of deformation or compression modulus:

$$E_c = \frac{\sigma}{\epsilon_{\text{total}}} = \frac{\sigma}{\epsilon_{\text{el}} + \epsilon_{\text{ir}}}$$

This modulus is thus based on the total measured strains, that is, elastic plus inelastic (irreversible or plastic) strains, ϵ_{el} and ϵ_{ir} , respectively.

2.87 Degree of Squeezing — The ratio of uniaxial compressive strength (q_c) of rock mass to the tangential stress ($\sigma_\theta = 2p$) defines the degree of squeezing which may be mild, moderate or high depending upon the value of $q_c/2p$.

2.88 Delay — Time interval (fraction of a second) between detonation of explosive charges.

2.89 Density (ρ) — Density of a rock is defined as its mass (m) per unit volume (V).

In the civil engineering usage; however, the term density is tacitly assumed to mean the unit weight of a material.

2.90 Dental Treatment — It is the treatment in the foundation or abutment of rock mass for safety of a masonry concrete dam. Normally, shear keys are provided between the foundation and the dam to improve resistance to sliding. If there is a fault or a shear zone or a zone of weak rock in the foundation, the soft rock is excavated to required depth below the dam base and backfilled with concrete.

2.91 Detonation — An extremely rapid and violent chemical reaction causing the production of a large volume of gas.

2.92 Detritus — A deposit of material produced by the weathering and disintegration of rocks that has been moved from its place of origin.

2.93 Dilatancy — Refers to a relative increase in volume for particular stress state, for example, packed sand expands when sheared.

2.94 Dip — The vertical angle that a stratum (or fault plane, or bending plane or joint plane or any planar feature), makes with the horizontal measured perpendicular to the strike of the structural surface,

or

The dip at right angles to the strike,

or

The slope of bed rock relative to the horizontal,

or

A pronounced depression in the land surface.

2.95 Discontinuity — The general term for any mechanical discontinuity in a rock mass having zero tensile strength. It is a collective term for most types of joints, weak bedding planes, weak schistosity planes, weakness zones and faults. The

ten parameters selected to describe discontinuities and rock masses are defined below:

- a) **Orientation** — Attitude of a discontinuity in space. Described by the dip direction (azimuth) and dip of the line of steepest inclination in the plane of the discontinuity. Termination in solid rock or against other discontinuity reduces the persistence.
- b) **Spacing** — Perpendicular distance between adjacent discontinuities. Normally refers to the mean or modal spacing of a set of joints.
- c) **Persistence** — Discontinuity trace length as observed in an exposure may give a crude measure of the areal extent or penetration length of a discontinuity. Termination in solid rock or against other discontinuities reduces the persistence.
- d) **Roughness** — Inherent surface roughness and waviness relative to the mean plane of a discontinuity. Both roughness and waviness contribute to the shear strength; large scale waviness may also alter the dip locally.
- e) **Wall Strength** — Equivalent compression strength of the adjacent rock walls of a discontinuity, may be lower than rock block strength due to weathering or alteration of the walls. An important component of shear strength if rock walls are in contact.
- f) **Aperture** — Perpendicular distance between adjacent rock walls of a discontinuity, in which the intervening space is air or water filled.
- g) **Filling** — Material that separates the adjacent rock walls of a discontinuity and which is usually weaker than the parent rock. Typical filling materials are sand, silt, clay, breccia, gouge and mylonite. Also includes thin mineral coatings and healed discontinuities, for example, quartz and calcite veins.
- h) **Seepage** — Water flow and free moisture visible in individual discontinuities or in the rock mass as a whole.
- j) **Number of Sets** — The number of joint sets comprising the intersecting joint system. The rock mass may be further divided by individual discontinuities.
- k) **Block Size** — Rock block dimensions resulting from the mutual orientation of intersecting joint sets, and resulting from the spacing of the individual discontinuities may further influence the block size and shape.

2.96 Disking (During Drilling) — When drilling into highly stressed hard rock, it is common for the core to emerge in regular discs, which are quite unrelated to the structure of the rock. The diskings occur when tensile stress developed due to stress relief exceeds the tensile strength of core. The thickness of the disc diminishes with increasing primitive stresses.

2.97 Dome — Hemispherically shaped roof of a cylindrical underground excavation.

2.98 Drainage Well — A vertical shaft constructed in masonry dams to intercept seepage before it appears at the down-stream face of the dam.

2.99 Drift — A horizontal underground passage,

or

Rock material of any sort deposited in one place after having been moved from another.

2.100 Drillability — Drillability is the measure of drilling speed at which a drill may penetrate different rocks.

2.101 Drilling Conditions — Rock drillability may be classified in five categories; fast, fast average, average, slow average and slow. The drilling conditions depend upon hardness, texture and fracture formation of a rock mass. A quantitative classification for drilling condition is available.

2.102 Drilling Pattern — The number, position, depth and angle of the blast-holes forming the complete round in the face of a tunnel or sinking pit.

2.103 Dry Density (ρ_d) — The mass of a rock sample or specimen after drying to constant mass at 150°C per unit gross volume of the sample or specimen.

2.104 Ductility — For a known or particular stress state (existing or imposed) to which a material can sustain plastic deformation without breaking or rupture. Elongation and reduction of area are common indices of ductility.

2.105 Dyke — A sheet like body of igneous rock which is discordant, that is, cuts across the bedding or structural planes of the host rock.

2.106 Dynamic Elastic Modulus (E_{dyn}) — It is the modulus of elasticity of rock mass under dynamic loads. During propagation of seismic waves through a rock mass, it is the dynamic modulus which determines the velocity of waves. The static modulus is less than the dynamic modulus. The ratio of static to dynamic modulus is called the reduction factor which can be estimated from the rock quality designation.

E

2.107 Effective Stress — Pore water pressure in rock is a factor affecting rock strength. The

effective normal stress is generally taken equal to the difference between normal stress and the pore water pressure. This is strictly valid only where pores, cracks and fractures are interconnected.

2.108 End Effect — In a uniaxial compression test in the laboratory or in the field, there is always some friction between the specimen and the leading surfaces. This friction restricts the lateral expansion of the ends of the specimen. This effect of lateral restraint is called end effect which often gives rise to conical fragments based on each platen.

2.109 Erosion — Process whereby soil or rock mass is loosened or dissolved and removed from any part of the earth's surface. It includes weathering, solution and transportation.

2.110 Escarpments or Scarps — A steep cliff or ridge that is formed by sudden earth movements, usually vertical but sometimes also horizontal along fault lines,

or

Any line of cliffs, or abrupt slope breaking the continuity of a land surface,

or

A fault line scarp is the one formed along the line of a fault.

2.111 Expanding Zone — Zone within broken zone expanding in volume or undergoing dilatation after failure.

2.112 Explosives — A substance which undergoes a rapid chemical change, with production of a large volume of gas.

F

2.113 Face — The solid surface of the unbroken part of the rock at the advancing end of the working place in a tunnel or adit.

2.114 Factor of Safety (of Slope) — The ratio of the total force available to resist sliding to total force tending to induce sliding.

2.115 Failure — Failing to perform an expected action. In a general sense, failure includes both fracture and flow.

2.116 Fatigue — Permanent structural change that occurs in a material subjected to fluctuating stress and strain. In general, fatigue failure occurs at a stress level below the elastic limit.

2.117 Fault — A fracture or a fracture zone along which there has been recognizable displacement, from a few centimetres to a few kilometres in scale. The walls are often striated and polished (slicken sided) resulting from the shear displacement. Frequently, rock on both sides of a fault is shattered and altered or weathered, resulting in fillings such as breccia and gouge. Fault widths

may vary from millimetres to hundreds of metres.

2.118 Fault Slip — A relative displacement of points on opposite sides of a fault measured on the surface of the fault, a minor fault, or slide.

2.119 Fault Trace — The line of intersection of a fault plane with the surface.

2.120 Fault Zone — A wide shattered belt rather than a fault plane.

2.121 Fill — Deposits of soil, rock or other material placed by man.

2.122 Finite Element — One of the regular geometrical shapes into which a body is subdivided for the purpose of numerical analysis.

2.123 Fissure — An extensive crack, break, or fracture in the rock.

2.124 Fold — Folds are wavy undulations which are developed in the country-rocks whenever the region is subjected to severe pressure or stress.

2.125 Foliation — The parallel disposition of the platy or flaky mineral is known as foliation.

This property is developed in metamorphic rocks only.

2.126 Formation — A group of rocks with recognizable and traceable boundaries, sufficiently alike lithologically to be mapped as a unit:

- a) *Massive* — A solid or dense rock mass with practically no seams,
- b) *Sheets* — A rock mass having layers or beds 1 to 3 m thick with thin horizontal seams,
- c) *Laminated* — A rock mass having thin layers of 30 to 100 cm thickness with horizontal seams with little or no gouge,
- d) *Seamy* — A rock mass with many open seams in horizontal and vertical positions, and
- e) *Blocky* — A rock mass, with wide open seams in all directions and filled with gouge, or which is shattered or fissured.

2.127 Foot Wall — The mass of rock beneath a discontinuity surface (zone).

2.128 Forepoling — Driving forepoles (pointed boards or steel rods) ahead of the excavation, usually over the last steel set erected, to furnish temporary overhead protection while installing the next set.

2.129 Fracture — A general term for any break in a rock, whether or not it causes any displacement due to the mechanical failure by stress. Fracture includes cracks, joints, faults, etc.

2.130 Fracture Intercept — It is the mean distance between successive fractures measured along an

intersecting straight line. All fractures irrespective of sets are to be counted. The least intercept is to be considered in any critical direction. It is classified as F_1, F_2, F_3, F_4 and F_5 for fracture intercepts of $> 200, 60-200, 20-60, 6-20$, and < 6 cm respectively. This notation is used in basic geotechnical description (*BGD*).

2.131 Full-Column-Anchored Bolts — It is a rock bolt which has been grouted throughout its length.

G

2.132 Gauge — Finely graded material occurring between the walls (of a fault, joint, etc) as a result of grinding movement. Filling material such as silt, clay, rock flour and other kinds of geological debris in joints, cracks, fissures, faults and other discontinuities in rock.

2.133 Gauge Length — Gauge length is the distance between two gauge points, taken on either side of the slot of flat jack that lies in the plane normal to it.

2.134 Gauge Points — These are arbitrary points marked on both sides of the slots and are used as observation points.

2.135 Grain Density (ρ_s) — The mass of the grains pulverized from rock specimens or sample, after drying to constant mass at 105°C , per unit volume of the grains, that is, the density of the pore free rock fabric. The ratio of grain mass (M_g) to grain volume (V_g).

2.136 Grain Mass (M_g) — The mass of the grains from a rock specimen or sample after drying to constant mass at 105°C .

2.137 Grain Volume (V_g) — The volume of the grains pulverized from rock specimens or a sample, that is, the bulk volume minus the pore volume.

2.138 Ground Arch — The rock located immediately above a tunnel which transfers the overburden load on to the rock located on the sides of the tunnel.

2.139 Ground Reaction Curve — Shows the relationship between support pressure and radial displacements of a tunnel wall. It shows that rock pressure depends upon the tunnel wall displacement and is not a unique property.

2.140 Grouting — Grouting is a process of injecting under pressure a slurry of fluid grout, or other suitable materials into the mass of a defective rock formation through a borehole to fissures and cracks in the hope that all fissures, joints and cavities will be sealed off against water in rock.

- a) *Consolidation Grouting* — Fractured rock mass is grouted to increase its strength and modulus of elasticity. As a loose rock mass is consolidated by grouting, this is called consolidation grouting.

- b) *Curtain Grouting* — (see 2.79).
- c) *Contact Grouting* — The gap between a dam and its foundation or between a tunnel lining and the surrounding rock mass is grouted under pressure to develop strong contact and bond between the structure and the rock mass.
- d) *Stage Grouting* — A method of grouting in which a hole is drilled and grouted in a descending or ascending sequence of stages.

2.141 Gunitite — A fluid mixture of fine sand, cement and water which is spray pumped through a nozzle and is used in sealing or protection work.

H

2.142 Hanging Wall — The mass of rock above a discontinuity surface.

2.143 Hardness — The resistance of minerals to scratching; it is a property by which minerals may be described relative to a standard scale of ten minerals known as Mohs' scale.

or

As used for rock in drilling and bit setting.

2.144 Heterogeneous (Non-Homogeneous) — A characteristic of a medium or a field of force that signifies that the medium has the properties that vary with the position.

2.145 Homogeneous Material or Medium — Having the same properties at all points.

2.146 Horizontal Rock Pressure — The rock pressure acting in horizontal direction on tunnel support is termed as horizontal rock pressure.

2.147 Hydraulic Conductivity of Fractures (K_f , L/T) — Hydraulic conductivity of fracture is defined as the ratio between the flow velocity in the conducting fracture and the hydraulic gradient or potential gradient across it.

2.148 Hydraulic Conductivity of Rock Mass (K) — Permeability with respect to water.

2.149 Hydraulic Fracturing — Creation of a fracture in rock by applying hydraulic pressure inside a borehole.

2.150 Hydraulic Gradient — Change of pressure head per unit of distance at a given point and in a given direction.

2.151 Hydraulic Monitoring — Monitoring of pore-water pressure and discharge of ground water in rock engineering structures. Hydraulic monitoring can give advance warning of impending failure much sooner than monitoring of deformation.

2.152 Hydrostatic Pressure — A state of stress in which all the principal stresses are equal (and there is no shear stress).

2.153 Hysteresis — A physical phenomenon met within the elastic and other behaviour of materials. When a body undergoes stress, the strain which results is a function of the stress. On releasing the stress, the strain lags behind; so the strain for any particular stress is greater while the stress is decreasing than when it is increasing. When the stress is removed altogether, a residual strain remains. This lagging behind is termed hysteresis, giving rise to an elastic hysteresis loop (a measure of internal friction).

I

2.154 Igneous Rocks — These are the primary rocks which have been molten at sometime in their history (for example, granite, basalt, gabbro etc).

2.155 Incompetent Rock — Rock incapable of standing in underground opening or steep slopes at the surface without support.

2.156 Inelastic Deformation — The portion of deformation under stress that remains permanently even after removal of stress.

2.157 Intact Rock — A material which can be sampled and tested in the laboratory and which is free of large scale structural features, such as joints, bedding planes, shear zones, and other kinds of rock defects.

2.158 Intrusive Rock — Rock formed due to the emplacement and consolidation of magma beneath the surface of the earth in pre-existing rock.

2.159 Isotropic Medium — Having the same physical properties in all directions (said of a medium with respect to elasticity, conduction of heat or electricity or radiation of heat or light).

J

2.160 Joint — A break of geological origin in the continuity of a body of rock along which there has been no visible displacement. A group of parallel joints is called a set and joint sets intersect to form a joint system. Joints can be open, filled or healed. Joints frequently form parallel to bedding planes, foliation and cleavages, and may be termed bedding joints, foliation joints and cleavage joints, accordingly.

2.161 Joint Alteration Number (J_a) — The joint alteration number represents the degree of alteration of the joint surface used in classification of a rock mass by Q-system.

2.162 Joint Frequency — Number of joints per metre for a given set of joints.

2.163 Joint Opening — Mean opening of surfaces of joints of the same set.

2.164 Joint Orientation — The orientation of joints is measured by the dip and strike of joints.

2.165 Joint Roughness Coefficient (JRC) — The joint roughness coefficient is a joint parameter which accounts for roughness of a joint profile. Its value is higher for rougher joints. The value of the joint roughness coefficient can be obtained by comparing joint surfaces with typical roughness profiles. Its value may also be obtained from a tilt test on rock joints surface.

2.166 Joint Roughness Number (J_r) — The joint roughness number represents the roughness of a joint profile used in classification of rock mass by Q-system.

2.167 Joint Set Number (J_n) — is defined as the number of joint sets present in the rock mass. The joint set number is used in the classification of a rock mass by the Q-system.

2.168 Joint Spacing — Spacing between two adjacent joints of the same set.

2.169 Joint Stiffness — There are two types of joint stiffnesses as follows:

- a) *Normal Stiffness of Joint (K_n , kg/cm³)* — It is defined as the normal pressure corresponding to unit closure of the joint. The ratio between the Young's modulus of the rock material and the normal stiffness of a clean unweathered joint is generally a constant which varies as 60, 25, 5 cm for continuous, discontinuous joints and cleavage planes respectively.
- b) *Shear Stiffness of Joints (K_s , kg/cm³)* — It is defined as the shear stress corresponding to unit slip across the joint. It is generally taken as the ratio of shear strength of joint and the peak slip which is normally taken equal to 1/100 of the length of joint surface along the slip direction. It should be noted that shear stiffness of a joint is very small compared to its normal stiffness.

2.170 Joint System — A group of two or more intersecting sets of joints.

2.171 Joint Wall Compressive Strength (JCS , kg/cm²) — It is a parameter of a joint wall which gives the compressive strength of the asperities of the joint surface in clean unweathered joints. The joint wall compressive strength may be taken as the minimum value of uniaxial compressive strength of rock cores, otherwise it may be obtained from the correlation between the Schmidt hammer number and the uniaxial compressive strength.

2.172 Joint Water Reduction Factor (J_w) — The parameter J_w is a measure of water pressure which has an adverse effect on shear strength of joints due to reduction in normal stress. Water may, in addition, cause softening and possible outwash in the case of clay filled joints.

K

2.173 Karst — A geologic setting where cavities are developed in massive limestone beds by solution or by flowing water. Caves and even underground river channels are produced into which surface run-off drains, and often results in the land above being dry and relatively barren.

L

2.174 Laminar Flow — The flow of a liquid in which the movement at any fixed point is continuous, steady and constant.

2.175 Landslides — The relatively perceptible downward and outward movement of slope-forming materials, such as rock, soil, artificial fill, or a combination of these materials with respect to the original mass. Also, earth and rock that become loosened from a hill side by the water of snow or an earthquake and which slides or falls down the slope.

2.176 Layer Thickness — It is the mean thickness of a layered zone of a rock mass. It is classified as L_1, L_2, L_3, L_4, L_5 for layer thicknesses of $> 200, 60-200, 20-60, 6-20$ and < 6 cm respectively. This notation is used in basic geotechnical description (*BGD*).

2.177 Lineation — Lineation is any one-dimensional feature in a rock shown on a rock surface. It may arise in any of the following ways:

- a) By a linear-parallel arrangement of minerals, either by growth or mechanical orientation;
- b) By the intersection of a planar structure with the rock surface;
- c) By the intersection of two planar structures such as bedding and cleavages;
- d) By the development of a series of small parallel packers in a planar structure such as microfolds, and
- e) By the deposition of elongated particles in a preferred orientation during sedimentation.

2.178 Liquefaction — The change in phase of a substance (say, a mass of a saturated sand) to the fluid state (say, sand as a loose, moving pouring body). A saturated non-cohesive soil mass can be in a fluid state if no intergranular pressure exists within it. Such a fluid state is commonly called liquefaction.

2.179 Liquid Limit (W_L) — The minimum moisture content at the point between the liquid and the plastic states of clay,

or

The water content expressed as a percentage of weight of oven-dry soil, at the boundary

between liquid and plastic states of consistency of soil.

NOTE — For the purpose of determination of liquid limit, it is defined as the water content at which a part of soil, cut by a groove of standard dimensions, will flow together for a distance of 12 mm under the impact of 25 blows in a standard liquid limit apparatus, or as the water content of a soil paste, prepared in a specified mould, into which a cone of specified dimensions and weight penetrates by 25 mm which dropped on to the paste in a specified manner.

2.180 Lithology — The physical character of a rock.

2.181 Long-Term Rock Pressure — This is the ultimate rock pressure on the supports in underground openings.

2.182 Loosening Pressure — Rock pressure exerted at supports by dead weight of loosened rock mass above a cavity.

2.183 Lugeon — A water intake of 1 l/m/min at an injection pressure of 10 bars, that is, 1 035 kN/m².

M

2.184 Machine Stiffness — The stiffness of a compression testing machine is defined as the ratio of force across the loading platens to the closure of platens after reducing the force to zero. To obtain complete stress-strain curves of rock, it is essential that machine stiffness is more than post-peak stiffness of the test specimen, otherwise failure of the specimen will occur in violent manner.

2.185 Macrofractures — These are cracks in rock wider than 0.1 mm. They may be up to several metres or more in length.

2.186 Mathematical Model — The representation of a physical system by mathematical expressions from which the behaviour of the system can be deduced with known accuracy.

2.187 Mass Movement — Unit movement of a portion of land surface as in creep, landslide or slip.

2.188 Mass-Wasting — The slow down slope movement of rock debris. A general term for a variety of processes by which large masses of earth materials are moved by gravity either slowly or quickly from one place to another.

2.189 Massive Rock — The rock mass is massive if the strength of the bond across partings or joints is comparable to the rock strength.

2.190 Micrograph — A micrograph is obtained by an electron microscope and shows the structure of particles of soil or rock.

2.191 Microseismic Noise — When rock material is overstressed and starts fracturing, specially in underground openings and rock slopes, microcracks develop giving rise to propagation of microseismic pulses which may be detected and

recorded through geophones as 'microseismic noise' or acoustic emission. Rock burst is an example of microseismic noise or acoustic emission.

2.192 Modulus of Deformation — See deformation modulus.

2.193 Modulus of Elasticity (E) — See axial Young's modulus.

2.194 Modulus Ratio — This is used to classify rock material and is defined as the ratio between the Young's modulus and the uniaxial compressive strength. The higher the value of the modulus ratio, the more brittle is the rock. The rock material is classified as high, medium and low modulus ratio for modulus ratios of > 500 , 500-200 and < 200 respectively.

2.195 Modulus Reduction Factor (MRF) — The modulus reduction factor is defined as the ratio between static elastic modulus of rock mass (E or E_{static}) obtained from *in-situ* tests and the elastic modulus of rock matter (E_r) obtained from laboratory test.

2.196 Modulus of Subgrade Reaction — It is defined as the ratio of normal pressure on the foundation and the corresponding settlement.

2.197 Mohr Circle of Stresses/Strain — A graphical representation of the components of stress/strain acting across the various planes at a given point, drawn with reference to axes of normal stress/strain and shear stress/strain.

2.198 Mohr Envelope — The envelope of a sequence of Mohr circles representing stress conditions at failure for a given material.

2.199 Mohs Hardness Scale — A scale of relative hardness of minerals arbitrarily reading from 1 to 10.

2.200 Mud Springs — When a joint strikes the ground water table below very soft or liquid (sloppy) ground, a spring will be formed. If mud comes out of the spring, it is called a mud spring.

2.201 Mylonite — A compact, chert like rock without cleavage but with a streaky or banded structure produced by the extreme granulation and shearing of rocks which have been pulverized and rolled during overthrusting or by the action of intense dynamic metamorphism, in general. Mylonite may also be described as a microbreccia with flow texture.

N

2.202 Neutral Pressure (u , F/L^2) — Pressure of water in the pores (voids) of a saturated medium of soil and rock. Also known as pore water pressure.

2.203 Normal Stress — The stress in a rock normal (perpendicular) to the shear stress.

O

2.204 Outbursts of Gas — In an opening, a rock mass may separate suddenly from the face and is crushed. This process may be accompanied by release of significant quantities of gas. The gases released by outbursts are most commonly methane carbon dioxide and nitrogen. Gas outbursts commonly take place in coal mines and can also take place in shales, etc.

2.205 Outcrop — That part of a stratum which appears at the surface.

or

Actual exposure of bed rock.

2.206 Over-Coring — A process of drilling around a previously installed gauge within a borehole to relieve the stresses around the gauge.

2.207 Over-Topping — In some slopes, failure takes place not by sliding of rocks but by overtopping of blocks of rocks. This type of failure occurs generally in steep slopes in thinly bedded rocks.

P

2.208 Particle Velocity — As a seismic wave propagates, it causes a particle of rock or soil to oscillate around its original position. The local velocity of motion of the particle is known as particle velocity. The ratio of particle velocity to the wave velocity gives the value of dynamic strain.

2.209 Pay Line — See B line.

2.210 Peak Shear Strength — Maximum shear strength along a failure surface.

2.211 Percolation — The movement of gravitational water through soil.

2.212 Perma-frost — Permanently, or perennially frozen ground.

2.213 Permeability (k , L/T) — Permeability is defined as that property of a porous material that permits the passage or seepage of fluids such as water or oil or gas (air) through its interconnecting voids. The overall permeability of a rock mass is denoted by K_c and is called the permeability of equivalent continuum.

2.214 pH Value — The negative logarithm of the hydrogen ion activity. For example pH 7 indicates a hydrogenion concentration (activity) of 10^{-7} mole/litre.

2.215 Piezometer — An open or closed tube or other device installed downward from the ground surface and used to measure the level to which the water from a given aquifer will rise under its full head.

2.216 Piezometric Surface — The surface at which water will stand in a series of piezometers.

2.217 Pilot Tunnel — A small tunnel excavated over the entire length or over part of a tunnel to explore ground conditions and assist in final excavation.

2.218 Pit — An excavation in the surface of the earth from which ore is obtained as in the large open pit mining or an excavation made for test purposes.

2.219 Plane of Weakness — Planes in rocks that affect its structural properties. The planes may be the result of joints, fractures, faults, bedding or partings.

2.220 Plane Wedge Failure — It is defined as the failure which occurs when a geological discontinuity such as a bedding plane, strikes parallel to the slope face and dips into the excavation at an angle greater than the angle of friction.

2.221 Plastic Deformation — Deformation that remains after the load causing it is removed. It is the permanent part of the deformation beyond the elastic limit of a material resulting in plastic strain, plastic flow and irrecoverable deformation.

2.222 Plastic Limit (W_p) — The water content at the lower limit of the plastic state of a clay. It is the minimum water content at which a soil can be rolled into a thread 3 mm in diameter without crumbling.

2.223 Plastic Zone — See broken zone.

2.224 Point Load Lump Strength Index (I_L , F/L^2) — It is the point load strength of a rock lump tested in point load tester.

2.225 Point Load Strength Index (I_s , F/L^2) — It is the point load strength of a rock core tested in point load tester. It is defined as the ratio of peak load at failure to the square of diameter of core. The standard size of the core is N_x size that is, about 50 mm.

2.226 Poisson Ratio (γ) — The negative of ratio of the slope of axial stress strain curve to the slope of the axial stress-diametrical strain curve for a cylindrical specimen subjected to uniaxial compression.

2.227 Pore Volume (V_p , L^3) — The volume of all pores contained within the gross external dimensions of a rock specimen or sample.

2.228 Pore Water Pressure — See natural pressure.

2.229 Porosity (n) — The volume of voids in a rock specimen expressed as a percentage of the gross volume (V_B) of the specimen.

2.230 Portal — The entry or exit point of a tunnel if it meets the ground surface.

2.231 Pre-splitting — See smooth blasting.

2.232 Pressure Bulb — The zone of stresses below a foundation, outside of which stresses are less than a limiting value. A 10 percent pressure bulb is defined as a pressure bulb or zone of stresses in which maximum stress is more than 10 percent of the foundation pressure.

2.233 Primary Lining — The lining initially placed inside a tunnel or shaft, usually to support the excavation. The primary lining may be of wood or steel sets with steel or wood lagging or rock bolts and shotcrete.

2.234 Primitive Stress — The ground is in a state of equilibrium before excavation of a tunnel or any underground opening. At this stage, the stresses at any point within the ground are termed as 'primitive', 'primary' or 'pre-excavation' stresses.

Q

2.235 Quarry — An excavation in the surface of the earth from which stone is obtained for crushed rock or building stone.

2.236 Quasi-Elastic — Quasi as if, as though it were, seemingly almost elastic, that is, considered as elastic for practical purposes.

R

2.237 Radius of Influence (e, L) — The 'radius of influence' is an empirical concept used in a bore hole permeability test. It is the distance from the borehole at which the influence of the test on the piezo metric head is no longer perceptible. Generally, one may consider that the radius of influence is between 100 and 1 000 times the radius of the test bore hole. (The radius of influence is greater in more permeable ground).

2.238 Raft Foundation — A raft is a continuous slab of RCC connecting all columns and walls.

2.239 Redox Potential — The stability of an element in a state of oxidation depends on the energy involved either in adding or subtracting electrons, and a quantitative measure for this is given by the redox potential.

A redox reaction is an oxidation-reduction one. If, in a cell, oxidation is produced at the anode and reduction at the cathode, the potential necessary is the redox potential. It is actually measured relative to a standard 'hydrogen electrode' taken as zero; this consists of platinum over which hydrogen is bubbled so as to produce a standard concentration of hydrogen ions.

Redox potential is a measure of corrosion of anchor bars, cables, etc.

2.240 Relaxation — Rate of reduction of stress in a material due to creep. An alternate term is stress relaxation.

2.241 Residual Shear Strength — Shear strength along a failure surface after a large displacement.

2.242 Residual Stresses — Residual stresses are defined in the sense of the theory of elasticity as 'locked-in' stresses associated with the previous rheological history of the rock. They may exist where viscoelastic effects of erosion have not completely relaxed. A visco-elastic substance cannot retain residual stresses indefinitely, but some material possessing a yield stress can do so.

2.243 Resonance — Where a small periodic force is applied to a system capable of oscillation, the system is usually set into forced oscillations of small amplitude and, as the frequency, f , of the excitant force approaches the natural frequency of the system, f_0 , at which point the system is said to be in resonance with the excitant force.

2.244 Rheology — Science dealing with the flow or deformation of matter. The study of time-dependent strain in both solids and liquids. Sometimes, rheology describes the study of all types of deformation, elastic and viscous, particularly the plastic flow of solids and flow of non-Newtonian liquids.

2.245 Rock — Any naturally formed aggregate of mineral matter occurring in large masses or fragments.

2.246 Rock Anchor — A steel rod or cable installed in a hole in rock to resist pull or shear force in principle same as the rock bolt, but generally used for rods longer than about four metres.

2.247 Rock Bolt — A steel rod placed in a hole drilled in rock used to reinforce the rock together. One end of the rod is firmly anchored in the hole by means of a mechanical device and/or grout, and the threaded (projecting) end is equipped with a nut and plate which bears against the rock surface. The rod can be pretensioned.

2.248 Rock Burst — Sudden explosive like release of energy due to the failure of a brittle rock of high strength in an underground opening.

2.249 Rock Fall — The relative free falling of newly detached segments of bed rock of any size, from cliff, steep slope, cave or arch.

2.250 Rock Mass — Rock mass is *in-situ* rock which has been rendered discontinuous by systems of structural features such as joints, faults and bedding planes.

2.251 Rock Mass Quality (Q) — A numerical index depending upon the rock mass quality and geological conditions, used to classify a rock mass. It is equal to $(RQD/J_n) (J_r/J_a) (J_w/SRF)$, where RQD = rock quality designation J_n = joint set number, J_r = joint roughness number, J_a = joint alteration number, J_w = joint water reduction factor and SRF = stress reduction factor.

2.252 Rock Mass Rating (RMR) — A numerical index depending upon the quality of a rock mass and geological conditions, used to classify a rock mass. It is the sum of ratings for uniaxial compressive strength, spacing, condition of joints, ground water conditions, *RQD* and joint orientation.

2.253 Rock Material — This is the smallest element of rock not cut by any fracture; there are always some micro-fractures in the rock material.

2.254 Rock Pressure (Vertical) — The rock pressure acting vertically on the tunnel supports is called vertical rock pressure.

2.255 Rock Quality Designation (RQD) — This is the percentage of sound cores recovered in pieces greater than or equal to 10 cm length with respect to the total core run.

2.256 Rock Reinforcement — The placement of rock bolts, rock anchors or tendons at a fairly uniform spacing to consolidate the rock and reinforce the rock's natural tendency to support itself. It is also used in conjunction with shotcrete on rock surface.

2.257 Rock Slide — The downward, usually rapid movement, of newly detached segments of the bed rock sliding on bedding planes, joint or fault surfaces or any other plane of separation.

2.258 Rock Weathering — The physical disintegration of rocks at or near the earth surface due to composition of minerals caused by the climatic change.

2.259 Roof Truss — The concept of roof truss support of openings in a rock mass is based on the development of a truss in the form of rock bolts and cable supports. Inclined holes are used at the ends which are tied up by a cable. The compression produced by the rock bolts and cables develops the effect of a truss within the rock mass in the opening.

2.260 Rotational Side — A relative displacement of points on opposite sides of a fault, measured on the surface of the fault, a minor fault or a slide.

2.261 Round — A set of holes drilled and charged in a tunnel or quarry which are fired instantaneously or with short-delay detonators.

2.262 Rupture — Failure of a material with development of fractures or shear planes. Deformation characterized by loss of cohesion.

S

2.263 Safe Blasting Criterion — Particle velocity has been found to be the best criterion for predicting damage to structures due to blasting vibrations. It has been recommended that particle velocity near any structure should not be allowed to exceed 50 mm per second.

2.264 Sagging — Usually occurs in sedimentary rock formations as separation and downward bending of sedimentary beds in the roof of an underground opening.

2.265 Sample — The rock submitted to the laboratory for testing.

2.266 Scabbing — Fracturing of rock in the form of slabs, due to interference between the wave front of an incident compressive wave and its reflection from rock surfaces.

2.267 Scaling — Removing loose pieces of rock in a tunnel after blasting.

2.268 Schistosity — The variety of foliation that occurs in coarse-grained metamorphic rocks and is generally the result of the parallel arrangement of platy and ellipsoidal mineral grains within the rock substance.

2.269 Sealed Distance — The sealed distance is a term used in predicting the effect of blasting vibrations on the buildings and other structures on the surface. Generally, it is taken to be $D/W^{1/2}$, where D is the distance from the source of blasting to the structure under consideration and W is the weight of explosive per delay.

2.270 Seamy — A rock mass with many thin layers.

2.271 Secondary Lining — The finally placed, or permanent structural lining of a tunnel which may be of concrete, steel or masonry.

2.272 Secondary Stress (Induced) — Creation of an underground opening modifies the stress distribution around the opening. These modified stresses are known as the induced, secondary or post-excavation stresses.

2.273 Sedimentary Rock — Rocks formed by the accumulation of sediments derived from the breakdown of earlier rocks by chemical precipitation, or by organic activity, for example, sandstone, limestone, shale, etc.

2.274 Self-Supporting Opening — In good quality rock masses, an opening may be made without using any kind of support system and it will stand for long periods of use. Such openings are called self-supporting openings.

2.275 Shaft — Generally, a vertical or near vertical excavation driven downward from the surface as access to tunnels, chambers or other underground workings.

2.276 Shear Failure (Failure by Rupture) — Failure in which movement is caused by shearing stresses in a rock mass.

2.277 Shear Modulus (Modulus of Rigidity) — The ratio of shear stress to shear strain for a material determined either from the slope of the tangent or of the secant of a stress-strain curve.

2.278 Shear Strength of a Rock Mass — The maximum resistance of a rock mass (including joints) to shearing stresses.

2.279 Shear Strength of Rock Material — The maximum resistance of a rock material (excluding joints) to shearing stresses.

2.280 Shear Zone — A zone in which shearing has occurred on a large scale so that the rock is crushed and brecciated.

2.281 Shield — A steel cylinder with open or closed face equal to the tunnel diameter for tunnel excavation in soft grounds.

2.282 Shock Waves — A shock wave is an inelastic wave. In fractured rock, the mass tangential modulus of elasticity increases with increasing strain. Any pulse will then tend to acquire a steep front and travel faster than the elastic waves. This phenomenon gives rise to a shock wave which has a great damaging potential or reflection from an open surface.

2.283 Short-Term Rock Pressure — Pressure generated immediately after excavation.

2.284 Shotcrete — A pneumatically applied concrete mix projected on an uneven rock surface. Shotcrete provides an effective protection of rock against weathering.

2.285 Silt — The term silt applies to unconsolidated material finer than sand and coarser than clay. In the non-technical sense, silt is the muddy, fine sediment carried and laid down by rivers or by the ocean in bays and harbours.

2.286 Sink Hole — Any slight depression in the land surface, specially one having no outlet, one of the hollows in limestone regions (limestone sinkholes) often communicating with a cavern or subterranean passage so that water running into it is lost.

2.287 Size Effect or Scale Effect — The strength of rocks decreases with increasing size of the specimen particularly under tensile stresses. This affect is known as size effect or scale effect.

2.288 Slabbing — The creation of axial cracks due to uniaxial compressive stresses, results in slabs of rock popping out into the cavity.

2.289 Slake Durability Index (I_d) — The percentage ratio of the final dry mass to the initial dry mass of a sample after being subject to one 10 minute slaking cycle in a slake durability apparatus.

2.290 Slaking — When an air-dried or oven-dried sample of fine particled soil is placed in water, the soil slakes. The force of surface tension draws the water into the voids and compresses the air trapped inside. The pressure in the air may become so high that the corresponding tension in the soil causes the slaking.

2.291 Slickenside — A polished and smoothly striated surface that results from friction along a fault plane.

2.292 Slip Lines — Orthogonal curves whose directions at any point bisect the angles between the principal axes at that point.

2.293 Smooth Blasting — Smooth blasting is used to minimize damage to the rock mass due to blasting vibrations. It is done by drilling closely spaced drill holes and blasting them by light charges.

2.294 Soil — All unconsolidated earth material of whatever origin that overlies bedrock, that has been in any way altered or weathered.

2.295 Spalling Rock — A rock mass under stress that yields thin slabs or wedges of rock by rapid failure. Slabs commonly form parallels to the walls or arch of an opening in rock.

2.296 Specific Gravity (G_m) — Ratio of weight of a given volume of dry rock to the weight of equal volume of distilled water at a standard temperature.

2.297 Specimen — The portion of the sample upon which the test is to be performed.

2.298 Spring Line — The place on the side of a tunnel where the tunnel starts curving into the arch.

2.299 Squeezing Ground Condition — A situation where a rock tries to squeeze inside the cavity soon after excavation, both in horizontal and vertical direct ons- (any rock can behave as squeezing rock if *in-situ* stresses are high).

2.300 Squeezing Pressure — Rock pressure exerted on supports by squeezing ground.

2.301 Stage Grouting — See grouting.

2.302 Stand Up Time — This is the time lapse between excavation and the instant when the first rock piece falls from the roof, in a newly excavated tunnel or opening.

2.303 Stick-Slip Oscillations — When a rock mass is sheared along smooth or rough joint surface, oscillations in the shear force vs slip curve may be observed. These are called stick-slip oscillations. Though the rate of shearing is constant, the actual slip takes place in jerks. While there is no motion, it is called stick and when motion starts, it is called slip. The total motion is called stick-slip motion.

2.304 Storage Co-efficient (S) — It is the change in the discharge out of an acquifer per unit change of head.

2.305 Strain Ellipsoid — The representation of the strain in the form of an ellipsoid into which a sphere of unit radius deforms and whose axes are the principal axes of strain.

2.306 Strain Energy Release Rate — It is the rate of strain energy released per unit area of the excavated surface in the underground minor tunnel openings. If the strain energy release rate is more than a limiting value, rock burst is likely to occur.

2.307 Strain Hardening — If upon loading beyond the yield point, the stress-strain curve continues to rise within the inelastic domain above the yield point, the material is said to be strain hardened.

2.308 Strain Softening — During uniaxial or tri-axial testing of rocks, it is generally observed that strength decreases after certain strain. This is known as strain softening.

2.309 Stratum — A layer or bed of rock or soil.

2.310 Strength Anisotropy Index — The ratio of the corrected point load strength indices for tests, perpendicular and parallel to planes of weakness in samples of an intact rock.

2.311 Stress Concentration Factor — Stress concentration takes place when a cavity is excavated in a rock mass. The stress concentration factor is defined as the ratio of tangential stress at a particular point along the periphery and the initial stress before excavation at that point. The higher the stress concentration factor, the greater are the chances of failure of the rock mass or rock burst.

2.312 Stress Ellipsoid — The representation of the state of stress in the form of an ellipsoid whose semi-axes are proportional to the magnitude of the principal stresses and lie in the principal directions. The coordinates of a point P on this ellipsoid are proportional to the magnitudes of the respective components of the stress across the plane normal to the direction OP , where O is the centre of the ellipsoid.

2.313 Stress Reduction Factor (SRF) — The parameter SRF is a measure of : (a) loosening pressure in the case of excavation through shear zones and clay bearing rock masses, (b) rock stress, q_c/σ_1 in a competent rock mass where q_c is uniaxial compressive strength of rock mass and σ_1 is the major principal stress before excavation, and (c) squeezing or swelling pressure in incompetent rock masses. SRF , hence, can be regarded as a total stress parameter.

2.314 Strike — It is the direction of a line formed by the inter-section of the structural surface (for example, a bedding or fault plane) and a horizontal plane.

2.315 Subsidence — Settlement of ground above the workings of underground operations.

2.316 Support — Structure or structural feature built into an underground opening for maintaining its stability.

2.317 Surface Energy — The surface of a crack is supposed to possess surface energy per unit area,

associated with rupturing of atomic bonds when a crack is formed. A crack can propagate only when the strain energy release rate is more than the surface energy of the crack.

2.318 Surface Porosity — It is the porosity of voids on a given surface of rock. It is defined as the area of voids to the total surface area of rock material.

2.319 Suspension Bolt — Rock bolts which are used to suspend weak rock layers or a fractured rock mass are known as suspension bolts. These bolts are anchored into the competent thick rock layer or rock mass.

2.320 Swelling — Swelling can be defined as a time-dependent volume increase of the natural ground caused by stress changes, increase in water content or by a combination of both:

- a) *Swelling Pressure Index (icc)* — The maximum axial stress recorded upon a radially and axially confined specimen after it is fully saturated;
- b) *Swelling Strain Index (sru)* — The maximum increase in axial strain, expressed as a percentage, of a radial confined specimen under a standard axial load upon saturation; and
- c) *Unconfined Swelling Strain (svc)* — The maximum increase in strain, expressed as a percentage, in a dimension of an unconfined specimen upon saturation.

T

2.321 Talus — Fragments which are broken off by the action of the weather from the face of a steep rock, accumulate at its foot, forming a sloping heap called talus.

2.322 Tectonic Creep — Fault creep of tectonic origin, also called slippage.

2.323 Tensile Strength (q_t) — It is ultimate strength of a material subjected to a tensile loading. Tensile strength is not a unique property of rock and depends very much upon the type of the test.

- a) *Uniaxial Tensile Strength* — Tensile strength of rock specimen subjected to uniaxial tensile stress.
- b) *Flexural Strength* — Tensile strength of a rock layer or beam subjected to bending moment. Flexural strength is obtained by a beam test on rocks and is significantly higher than the uniaxial tensile strength.
- c) *Brazilian Tensile Strength* — Tensile strength obtained from the Brazilian test on rock disc.

2.324 Tension Crack — Vertical cracks which occur on the top terrace of a slope which is under distress. These cracks are called tension cracks, as they develop due to existence of tensile stresses in that region. Tension cracks can also occur along the slope but this is usually rare.

2.325 Terrace — Any level topped surface, with a steep escarpment, whether it be solid rock or loose material. It is step like in character.

2.326 Texture — It is the relationship between the grains of minerals forming a rock.

- a) *Porous* — Rock material with cellular structure and large voids;
- b) *Fragmental* — Rock material having fragments of minerals which are loosely packed;
- c) *Granitoid* — Rock material with grains large enough to be readily recognized — average grain granite;
- d) *Porphyritic* — Rock with large crystals in fine grained mass; and
- e) *Dense* — Rock with grain structure too small to identify with the naked eye.

2.327 Thermal Stress — Internal stress, caused in part by uneven heating.

2.328 Three-Dimensional Wedge Failure (of Slopes) — When two discontinuities strike obliquely across the slope face and their line of intersection day lights in the slope face, the wedge of rock testing on these discontinuities will slide down along the line of intersection, provided this is greater than the angle of friction.

2.329 Throw — The projection of broken rock during blasting.

2.330 Tight — Rock remaining within the minimum excavation lines after completion of a blast-round.

2.331 Toughness — Extent to which a material absorbs energy without fracture.

2.332 Trench — Usually a long, narrow, near vertical sided cut in rock or soil such as is made for utility lines.

2.333 Tunnel — A passage in rock or soil open at both ends.

2.334 Tunnel Supports — A support system used in a tunnel is known as a tunnel support. These are of two types:

- a) *Stiff Supports* — These are supports which do not deflect significantly with increase in rock pressure and are known as rigid or stiff rock supports such as concrete linings or steel supports of every heavy section; and

- b) *Flexible Support* — Those supports which deflect significantly with increase in rock pressures are known as flexible supports such as steel supports of thin section with gravel packing and shotcrete. The advantage of a flexible support system is to dissipate the strain energy stored in the rock mass by allowing squeezing of rock mass.

U

2.335 Ultimate Rock Pressure — Pressure which will eventually develop on supports during the life time of an opening.

2.336 Unconfined Compressive Strength — See uniaxial compressive strength.

2.337 Unconfined Swelling Strain (S_{vc}) — The maximum increase in strain, expressed as a percentage, in a dimension of an unconfined specimen upon saturation.

2.338 Undulating Rock Profile — If the profile of the rock mass below a soil cover is undulating, it is called an undulating rock profile. This may happen in soluble rocks.

2.339 Uniaxial Compressive Strength (q_c , F/L^2) — The maximum uniaxial compressive load carried by a right cylindrical specimen of rock divided by the cross-sectional area of the sample. It is classified as S_1 , S_2 , S_3 , S_4 , S_5 for uniaxial compressive strengths of 2 000, 600-2 000, 200-600, 60-200 and < 60 kg/cm², respectively. This notation is used in the basic geotechnical description (*BGD*).

- a) *Unit Weight (γFL^{-3})*
- b) *Dry Unit Weight* — γ_d (FL^{-3}) — The weight of even dry rock per unit of total volume of rock.
- c) *Saturated Unit Weight* — γ_{sat} (FL^{-3}) — The unit weight of a rock material when saturated.

2.340 Unsupported Span — It is the distance between face of excavation and first line of support or the width of the opening whichever is minimum. It affects the stand-up time.

2.341 Uplift Pressure — Either the upward force on a dam base due to water pressure in the foundations or the upward heaving of earth caused by the escape of water under high pressure from a dam or other confined area.

V

2.342 Vesicles — Voids formed due to emanation of gases in flows of volcanoes.

2.343 Virgin Rock Stresses — *See* Primitive stress.

2.344 Void Index (I_v) — Void ratio defined as the mass of water contained in a rock sample after a one hour period of immersion, as a percentage of its initial desiccator-dry mass.

2.345 Volumetric Joint Count (J_v) — It is the total number of joints in a unit cube of rock mass of 1 m^3 volume.

W

2.346 Water, Interstitial — Water that exists in the interstices or voids in rock, soils or other kinds of porous media.

2.347 Water, Meteoric — Water that is in or derived from the atmosphere. The term has been used in various ways, sometimes to include all sub-surface water of external origin and sometimes to include only that derived by absorption, excluding specially the connate ocean water.

2.348 Wave Front — The surface which is the locus of all points, having their motion in identical phase propagating in a wave, the direction of propagation being perpendicular to the wave front.

2.349 Weathering — The process of rock breakdown and decomposition instigated by external agencies, such as wind, rain, change in temperature, plants, etc. Two main types exist, namely, mechanical (physical) and chemical. The former involves break-up processes, the latter chemical alteration. Weathering together with subsequent transportation comprise erosion.

Y

2.350 Yield Stress — The stress at which strain increases without accompanying increase in stress. It is an indication of maximum stress that can be developed in a material without causing plastic deformation. It is the stress at which a material exhibits a specified permanent deformation and is a practical approximation of elastic limit.

2.351 Yielding Supports — Supports capable of undergoing substantial deformation so as to modify stress distribution around the supports.

2.352 Young's Modulus — *See* axial Young's modulus.

Z

2.353 Zone of Weathering — That layer of superficial deposits subject to weathering and broadly coinciding with the belt of soil water.

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